PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 13 June 2000 (13.06.00)	
International application No. PCT/GB99/03953	**Applicant's or agent's file reference** PJA/C088296PWO
International filing date (day/month/year) 29 November 1999 (29.11.99)	**Priority date** (day/month/year) 02 December 1998 (02.12.98)
Applicant TAYLOR, Christopher, John et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

16 May 2000 (16.05.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer S. Mafla
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

09/857044

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
PJA/C088296PWO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 99/03953	29/11/1999	02/12/1998
Applicant		
THE VICTORIA UNIVERSITY OF MANCHESTER et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readbie form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

   [ ] as suggested by the applicant.

   [X] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/GB 99/03953

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GRAHAM D B ET AL: "Face recognition from unfamiliar views: subspace methods and pose dependency" PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION (CAT. NO.98EX107), PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION, NARA, JAPAN, 14-16 APRIL 1998, pages 348-353, XP000884382 1998, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-8186-8344-9 cited in the application the whole document	1-7

-/--

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 March 2000	23/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Granger, B

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	MOGHADDAM B ET AL: "Beyond eigenfaces: probabilistic matching for face recognition" PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION (CAT. NO.98EX107), PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION, NARA, JAPAN, 14-16 APRIL 1998, pages 30-35, XP000884293 1998, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-8186-8344-9 cited in the application the whole document	1-7
A	DUVDEVANI-BAR S ET AL: "A similarity-based method for the generalization of face recognition over pose and expression" PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION (CAT. NO.98EX107), PROCEEDINGS THIRD IEEE INTERNATIONAL CONFERENCE ON AUTOMATIC FACE AND GESTURE RECOGNITION, NARA, JAPAN, 14-16 APRIL 1998, pages 118-123, XP000884299 1998, Los Alamitos, CA, USA, IEEE Comput. Soc, USA ISBN: 0-8186-8344-9 cited in the application the whole document	1-7

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G06K 9/00

A1

(11) International Publication Number: WO 00/33240

(43) International Publication Date: 8 June 2000 (08.06.00)

(21) International Application Number: PCT/GB99/03953

(22) International Filing Date: 29 November 1999 (29.11.99)

(30) Priority Data:

9826398.1	2 December 1998 (02.12.98)	GB
9922807.4	28 September 1999 (28.09.99)	GB

(71) Applicant *(for all designated States except US)*: THE VICTORIA UNIVERSITY OF MANCHESTER [–/GB]; Oxford Road, Manchester M30 9PL (GB).

(72) Inventors; and

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(74) Agent: ALLMAN, Peter, John; Marks & Clerk, Sussex House, 83–85 Mosley Street, Manchester M2 3LG (GB).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

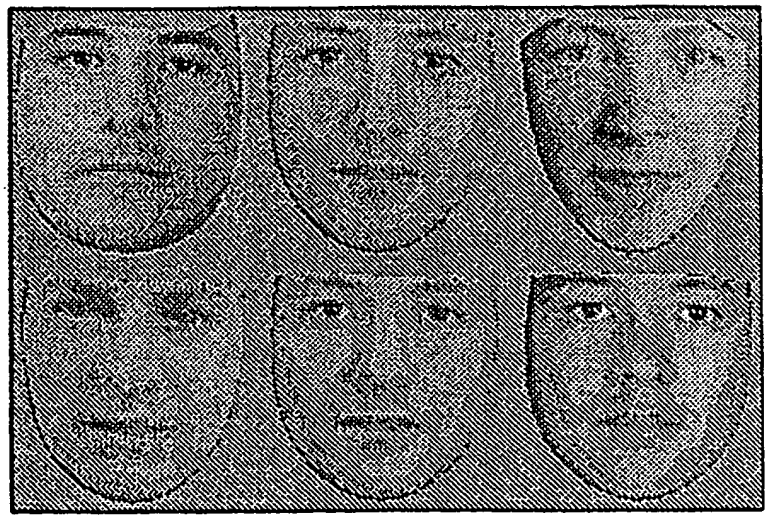
Published

With international search report.

(54) Title: FACE SUB–SPACE DETERMINATION

(57) Abstract

A method of determining face sub–spaces. The method comprises making initial estimates of the sub–spaces, for example lighting, pose, identity and expression, using Principle Component Analysis on appropriate groups of faces. The method further comprises applying an iterative algorithm to image codings to maximise the probability of coding across these non–orthogonal sub–spaces, obtaining the projection on each sub–space, and recalculating the spaces.



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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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caricatures: On the psychological consistency of computer face recognition. 2nd Face and Gesture, pages 4-10, 1996.] have suggested that using a shape-free coding provides a ready means of doing this, at least the when the range of pose-angle is relatively small, perhaps $\pm 20^{o}$ [T. Poggio and D. Beymer. Learning networks for face analysis and synthesis. Face and Gesture, pages 160-165, 1995.]. In this embodiment of the invention, the correspondence problem between faces is first solved by finding a pre-selected set of distinctive points (corners of eyes or mouths, for example) which are present in all faces. This is typically performed by hand during training. Those pixels thus defined as being part of the face can be warped to a standard shape by standard grey-level interpolation techniques, ensuring that the image-wise and face-wise co-ordinates of a given image are equivalent. If a rigid transformation to remove scale, location and orientation effects is performed on the point-locations, they can then be treated in the same way as the grey-levels, as again identical values for corresponding points on different faces will have the same meaning.

Although these operations linearise the space, allowing interpolation between pairs of faces, they do not give an estimate of the dimensions. Thus, the acceptability as a face of an object cannot be measured; this reduces recognition [N. P. Costen, I. G. Craw, G. J. Robertson, and S. Akamatsu. Automatic face recognition: What representation ? European Conference on Computer Vision, vol 1, pages 504-513, 1996]. In addition, redundancies between feature-point location and grey-level values cannot be described. Both these problems are addressed in this embodiment of the invention by Principal Components Analysis (PCA). This extracts a set of orthogonal eigenvectors Φ from the covariance matrix of the images (either the pixel grey-levels, or the featurepoint locations). Combined with the eigenvalues, this provides an estimate of the dimensions and range of the face-space. The weights **w** of a face **q** can then be found,

$$w = \Phi^{T}(q - \overline{q}) \qquad (1)$$

and this gives the Mahalanobis distance

$$d^{2}_{i\to 2} = \sum_{i=1}^{N} \frac{(w_{1i} - w_{2i})^{2}}{\lambda_{i}} \qquad (2)$$

spaces. This process is iterated to obtain a set of stable, and rather more orthogonal, sub-spaces which code only the desired features.

If n_s subspaces are used, each described by eigenvectors $\phi^{(j)}$ with the associated eigenvalues $\lambda^{(j)}$ for a given ^{flu}q the projection out of the combined sub-spaces is given by:

$$q' = \sum_{j=1}^{n_s} \phi^{(j)} w^{(j)} + \bar{q} \qquad (4)$$

with the constraints that

$$E = \sum_{j=1}^{n_s} \sum_{i=1}^{N_j} \frac{(w_i^{(j)})^2}{\lambda_i^{(j)}} \qquad (5)$$

be minimised. Thus if M is the matrix formed by concatenating $\phi^{(j=1,2...)}$ and D is the diagonal matrix of $\lambda^{(j=1,2...)}$,

$$w = (DM^T M + I)^{-1} DM^T (q - \bar{q}) \qquad (6)$$

and this also gives a projected version of the face

$$q = (DM^T)^{-1}(DM^T M + I)w + \bar{q} \qquad (7)$$

with $w_i = 0$ for those sub-spaces not required.

The first stage of implementing the invention was to subtract the overall mean from each face, so ensuring that the mean of each sub-space was as close to zero as possible. Separate principle component analyses (PCAs) were then performed upon the image sets, discarding any further difference between the group and overall means. The covariance matrices for the identity and lighting sub-spaces were calculated as

$$C_T = \frac{1}{n} \sum_{i=1}^{n} (q_i - \bar{q})^T \qquad (8)$$

the pose and expression used

$$C_w = \frac{1}{n_o n_p} \sum_{i=1}^{n_p} \sum_{k=1}^{n_o} (q_{ki} - \bar{q}_i)(q_{ki} - \bar{q}_i)^T \qquad (9)$$

where n_o is the number of observations per individual, and n_p is the number of individuals, and $\bar{q}_i$ the mean of individual i. Although all the eigenvectors implied by

Convergence of the method was estimated by taking the Mahalanobis distances between all the images on each of the sub-spaces. A Pearson product-moment correlation was taken between the distances of successive iterations, and allowed to converge to machine accuracy, although in practice a slightly lower value would achieve the same results with reduced processing time. The method gave a relatively smooth set of correlation coefficients as shown in Figure 5, converging in approximately seven iterations (Figure 5 shows changes in the correlations between the Mahalanobis distances separating all the images on the multiple space between iteration n and n-1). Since only 99.99% of the variance in the ensemble to avoid problems with numerical accuracy, practical convergence was achieved by the fourth iteration.

Since the iterations involved the inclusion of information which failed to be coded on the previous iteration, it should be expected that the difference between original and projected images should decline. This should apply to both ensemble and non-ensemble images as the eigenfaces become more representative.

This was tested by projecting the images through the combined spaces (using Equations 6 and 7) and measuring the magnitude of the errors. This was performed for both the ensemble images and also for a large test set (referred to as 'Manchester'), first used in [A. Lanitis, C. J. Taylor, and T. F. Cootes. An automatic face identification system using flexible appearance models. British Machine Vision Conference, pages 65-74, 1994]. This consisted 600 images of 30 individuals, divided in half: a gallery of 10 images per person and a set of 10 probes per person. As can be seen in Figure 6, in both cases, the errors quickly dropped to a negligible level (Errors quickly decline to a negligible level in both cases. Errors on the individual sub-spaces remain high (4,000 to 11,000)). As a comparison, the two sets have mean magnitudes (total variance) of 11345 and 11807, measured on the appearance-model eigenweights.

The level of normalisation was measured on the Manchester set, calculating the identity weights using Equation 6, and finding the person-mean $\overline{w_i}$. Better removal of contaminating variance should reduce the variance for each individual, relative to this mean. The variance,

$$V = \frac{1}{n_o n_p N} \sum_{i=k}^{n_p} \sum_{k=1}^{n_o} \sum_{j=1}^{N} (\overline{w}_{ij} - w_{kij})^2 \qquad (12)$$

was calculated. The results of this test in Figure 7 show a steady decline in the identity sub-space variance (Figure 7 shows the mean within-person variances for the different sub-spaces as a function of iteration number). The only exception to this is the value for iteration two; this is unusual in having a large increase in the number of dimensions, without an opportunity to re-distribute this variation into the other sub-spaces.

The results of projecting the faces into the other sub-spaces are shown, as is the variance in the appearance model. As might be expected, these are all higher than the identity sub-space value, and do not show marked declines as the iterations progress. Indeed, the pose variance increases slightly.

Recognition was also tested on the Manchester set, coding the images on the final rotated space. The Appearance Model used to provide correspondences, did not give completely accurate positions, lowering recogntion. The pooled covariance matrix was found using Equation 9 on the $\mathbf{w}_i$. This allowed

$$d^2_{i-k} = (\overline{w}_i - w_k)^T C_W^{-1} (\overline{w}_i - w_k), \qquad (13)$$

where $1 \leq k \leq (n_o x n_p)$ to give Mahalanobis distances to the mean images. A recognition was scored when the smallest d had the same identity for i and k. The results are shown in Figure 8 (which shows recognition rates for Euclidean average-image matching), and demonstrate that relative to the base condition, recognition improves by about one percent on iteration 4. Also shown are the effects of projecting the test images through the complete space to obtain the lighting - pose - expression normalised version, and then coded on the final rotated space. This does not produce an improvement in recognition. It should be noted here that there may well be contingent, non-functional correlations between parameters on different sub-spaces for individuals (for example, a consistent tendency to look up or down), whose omission may trade off against theoretically preferable eigenfaces.

Once an accurate coding system for faces has been achieved, the major problem is to ensure that only a useful sub-set of the codes are used for any given manipulation or measurement. This is a notably difficult task, as there are multiple,

non-orthogonal explanations of any given facial configuration. In addition, it is typically the case that only a relatively small portion of the very large data-base required will be present in the full range of conditions and with the labels needed a simple linear extraction.

The invention overcomes these problems by using an iterative recoding scheme, which takes into account both the variance of and covariance between the sub-spaces which can be extracted to span sets of faces which vary in different ways. This yields 'cleaner' eigenfaces, with lower within appropriate group variance and higher inappropriate group variance. Both these facts reflect greater orthogonality between the sub-spaces. In addition, recognition on an entirely disjoint test set was improved, although marginally. The invention may be applied to tracking, lip-reading and transfer of identity from one person to another.

CLAIMS

1. A method of determining face sub-spaces, the method comprising making initial estimates of the sub-spaces, for example lighting, pose, identity and expression, using Principle Component Analysis on appropriate groups of faces, applying an iterative algorithm to image codings to maximise the probability of coding across these non-orthogonal sub-spaces, obtaining the projection on each sub-space, and recalculating the spaces.

2. A method of determining face sub-spaces, the method comprising:

a. generating a first series of initial images in which a first predetermined facial property is modified,

b. generating a second series of initial images in which a second predetermined facial property is modified,

c. coding each series of images according to the variance of the images to obtain an estimated sub-space for each facial property,

d. concatenating the sub-spaces to provide a single over-exhaustive space,

e. approximating each image of the first and second series on the over-exhaustive space to obtain approximated versions of each image on each estimated property subspace,

f. generating overall approximated versions of each image on the whole over-exhaustive space,

g. comparing the overall approximated version of each image with the initial image to determine an error value for each image,

h. sub-dividing the error value for each image into a sub-error for each estimated property sub-space in proportion to the variance of that sub-space,

i. combining each sub-error for each image with the approximated version of that image on the estimated property sub-space, to obtain a new approximated version in the property sub-space for each image,

j. coding the new approximated versions of the images according to their variance to obtain new estimated sub-spaces.

3. A method of determining face sub-spaces according to claim 2, further comprising approximating each image on the new estimated sub-spaces as described in steps 'a' to 'j' and then repeating steps 'd' to 'j' until the sub-spaces have stabilised.

4. A method of determining face sub-spaces according to claim 2 or claim 3, wherein three or more series of images are generated, a different predetermined facial property being modified in each series.

5. A method according to claim 4, wherein the predetermined facial properties are categorised as at least some of identity, expression, pose, lighting and age.

6. A method according to any of claims 2 to 5, wherein at least one further series of images is generated, a further predetermined facial property being modified in the series.

7. A method of determining face sub-spaces substantially as hereinbefore described.

09/857044

PATENT COOPERATION TREATY

REC'D 09 MAR 2001
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
PJA/C088296PWO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB99/03953	29/11/1999	02/12/1998
International Patent Classification (IPC) or national classification and IPC G06K9/00		
Applicant THE VICTORIA UNIVERSITY OF MANCHESTER et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 7 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
16/05/2000	07.03.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Casteller, M Telephone No. +49 89 2399 2666

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/03953

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1-3,5-7,9	as originally filed			
4,8,10-12	as received on	09/01/2001	with letter of	03/01/2001

Claims, No.:

1-7	as received on	09/01/2001	with letter of	03/01/2001

Drawings, sheets:

1/4-4/4	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 6, 7.

because:

   ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

   ☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 6, 7 are so unclear that no meaningful opinion could be formed (*specify*):
   see separate sheet

   ☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

   ☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination report cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.

   ☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-5
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-5
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-5
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item III

Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. Independent claim 6 does not meet the requirements of Article 6 and Rule 6.3(a) PCT in that it does not clearly define the scope of the monopoly for which protection is sought since said claim is expressed in vague and ambiguous terms.
The vague, functional and excessively concise wording of this claim does not allow the skilled reader to even only guess how the recited iterative algorithm is supposed to "maximise the probability of coding across these non-orthogonal sub-spaces".
Independent claim 7 recites a method of determining face sub-spaces defined only by a completely undefined reference to the description in its entirety.
The wording of both claims 6 and 7 is unclear (Article 6 PCT) to such an extent that it appears impossible to even only attempt an assessment of novelty and inventive step for such a broadly formulated claim.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

2. The documents cited in the International Search Report, all cited in the application, only indicate that it is in general known to use autocorrelation techniques in the field of human face recognition for determining eigenvectors (e.g. eigenfaces, eigensignatures) of a learning set of face images. These eigenvectors are determined for series of images in which only a chosen visual feature varies, e.g. one series for different illumination conditions, one series for different poses of one or more identical faces, etc. The eigenvectors can be thus grouped in sets that define facial sub-spaces, each sub-space associated to a given visual feature (e.g. pose, or facial expression).
However, there is the problem that these sub-spaces are in fact not perfectly orthogonal. In other words, not only the desired visual feature is coded by the eigenvectors of a given sub-space, but also an unknown mixture of the other types of visual features, depending on the initial training series of face images.

3. The present invention discloses a method as set out in claim 1 for determining sub-spaces of (human) facial variations.
Initial series of face images, each series associated to a given facial property (e.g. pose, illumination, expression, etc.), are analysed, and a plurality of eigenvectors ($\phi^{(j)}$) (and eigenvalues ($\lambda^{(j)}$)) determined for each series, thereby determining an estimated sub-space for each facial property (claim 1, steps "a." to "c.").
An over-exhaustive space is then determined (claim 1, step "d.") by concatenating said eigenvectors (matrix M, cf. page 8, line 9, page 9, line 3).
By re-coding each face image (q) of the initial series on the basis of the this over-exhaustive space, approximated versions (q'_j) thereof are generated for each estimated facial property sub-space, and an error value (r_j) between each such approximated version and the corresponding initial image can be determined (claim 1, steps "e." to "g.").
This error value is split into sub-error values, each sub-error value associated to a given estimated facial property sub-space and being proportional to the variance of that sub-space (claim 1, step "h.").
For each estimated facial property sub-space, a new approximated version of each face image of the initial series is obtained by combining the initial approximated version and these sub-error values (claim 1, step "i.").
These new approximated versions can be again analysed (determining updated eigenvectors), thereby determining a new estimated sub-space for each facial property with improved orthogonality (claim 1, step "j.").
The method can be iterated (from steps "d." to "j.", cf. claim 2), thereby determining a sequence of newly estimated sub-spaces for each facial property, the sub-spaces being progressively more stable and having greater orthogonality with respect to each other.
Consequently, the subject-matter set out in present claims 1 to 5, and particularly in claim 1, is considered to be novel and non-obvious with respect to the disclosures of the available prior art. It is also evident that the invention is industrially applicable.
The requirements of paragraphs (1) to (4) of Article 33 PCT are thus met.

Re Item VII
Certain defects in the international application

4. None of the present claims is provided with reference signs placed in parentheses (Rule 6.2(b) PCT), which in the present case would have been appropriate for indicating the necessary correspondence between claimed and described features.

Re Item VIII
Certain observations on the international application

5. The application does not meet the requirements of Article 6 PCT, because independent claims 1 and 6 are not clear.

6. Present independent claims 1 and 6 have only partially overlapping scope, and it is not clear from their wording how the claimed features are supposed to correspond to each other.
It does not seem that such a multiplicity of independent claims is strictly necessary and hence the number would not appear to be reasonable (Rule 6.1 (a) PCT).
The claims should have contained only the minimum number of independent claims necessary to clearly and sufficiently define the invention, with dependent claims as appropriate, Article 6 and Rule 6.4 PCT.
In the present case, it would have been considered appropriate to use only one independent claim per category.

7. Furthermore, independent claim 6 considered in isolation does not meet the requirements of Article 6 and Rule 6.3 (a) PCT in that it does not clearly define the scope of the monopoly for which protection is sought since said claim is expressed in vague and ambiguous terms.
The vague, functional and excessively concise wording of this claim does not allow the skilled reader to even only guess how the recited iterative algorithm is supposed to "maximise the probability of coding across these non-orthogonal sub-spaces".